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Title:

# Stimulus Pairing Training in Children with Autism Spectrum Disorder

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## 1. Introduction

In early training for children with autism spectrum disorders (ASDs) and other developmental disabilities, matching-to-sample (MTS) tasks are widely used (Serna, Dube, & McIlvane, 1997; Wilkinson & McIlvane, 2002). In a MTS task, a child is reinforced if s/he chooses one stimulus corresponding to another stimulus (i.e., a sample stimulus) from among two or more choice stimuli (i.e., comparison stimuli). For example, if the auditory stimulus “apple” is presented as a sample stimulus, a child's choice of a picture of an apple from among multiple comparison stimuli of pictures is reinforced. As a result, the child can always choose the picture of an apple in the presence of the auditory stimulus “apple.” (That is, the child learns an auditory stimulus => picture stimulus relation. The left side of the arrow represents the sample stimulus, and the right side represents the comparison stimulus.) Furthermore, many studies have demonstrated that MTS tasks facilitated not only trained relations but also untrained relations. For example, when a child is trained in two relations in a MTS task (e.g., A => B and B => C relations), four types of relations are derived in the MTS test without a direct training history: reflexive relations (i.e., A => A, B => B, and C => C relations), symmetrical relations (i.e., B =>A and C => B relations), transitive relations (i.e., A => C relation), and equivalence relations (i.e., C => A relation). The emergences of these derived relations in MTS tasks are termed as stimulus equivalence (Sidman & Tailby, 1982; Sidman, Wynne, Maguire, & Barnes, 1989). The stimulus equivalence paradigm has often been used to teach various language or cognitive skills to children with ASDs and other developmental disabilities (Yamamoto, 1994; Noro, 2005).

However, many studies have revealed that people with developmental disabilities or young children with typical development find it difficult to learn some stimulus relations through standard MTS tasks (e.g., Saunders & Spradlin, 1989; Pilgrim, Jackson, & Galizio, 2000; Doughty & Saunders, 2009). Thus, in an applied setting, there is a need to determine the variables that encourage the learning of stimulus relations in MTS tasks and develop procedures other than MTS tasks to enable individuals to learn the relations among stimuli more efficiently and effectively.

As an alternative to MTS tasks, some studies suggest observation of stimuli that are successively paired to learn these stimulus relations (e.g., Leader, Barnes, & Smeets, 1996; Smeets, Leader, & Barnes, 1997; Tonneau & Gonzalez, 2004). In this procedure (called stimulus pairing training in the following sections), the learner does not need to choose one stimulus, so that there is no incorrect choice. Thus, the stimulus pairing is more efficient than a MTS task in terms of the number of responses required to learn the relations. In MTS tasks, choice responses of comparison stimuli are known to be controlled by various types of stimulus controls (Fields, Garruto, & Watanabe, 2010). These controls include not only the relevant controls to perform the MTS task correctly but also several irrelevant ones. For example, a child’s choice of comparison stimulus may not be controlled by its corresponding sample stimulus (i.e., relevant control) but by its position (i.e., position preference) or by the comparison stimulus itself (i.e., stimulus preference). Furthermore, in MTS tasks, these irrelevant stimulus controls may be reinforced incidentally. Moreover, children with ASDs tend to persist in their choice of comparison stimuli controlled by these learned irrelevant controls. If these children could learn stimulus relations through stimulus pairing procedures, we would be able to decrease the possibilities of their learning the irrelevant stimulus controls. In addition, a previous study of stimulus pairing (Smeets et al., 1997) suggests the possibility that 5-year-old children with typical development could learn more effectively through stimulus pairing than through MTS tasks. Despite the potential efficiency and effectiveness of stimulus pairing, very few studies have examined the possibility of stimulus pairing as an instructional procedure for children with ASDs.

In this study, we examined the effectiveness of stimulus pairing for two boys with ASDs. In most previous studies of stimulus pairing, the paired stimuli were both visual stimuli (i.e., visual-visual relations). However, in language and cognitive skills training, children need to learn stimulus relations that include different modes, such as auditory and visual stimuli (i.e., auditory–visual relations). Thus, we also examined in one of the boys with ASDs whether the stimulus pairing procedure could also promote the learning of stimulus relations between auditory and visual stimuli.

# 2. Methods

## 2.1. Participants

The participants were two boys who had been diagnosed with ASDs.

Ken was an 11-years-7-months old boy who was enrolled in a special education class at a public elementary school. On the Wechsler Intelligence Scale for Children–Third edition (WISC–III), he had a measured verbal IQ of <43, performance IQ of 89, and full-scale IQ of 69. Ken could understand and speak easy sentences consisting of two or three words, and he could also read all Japanese syllabary characters, “Hiragana,” and some Chinese characters, “Kanji.” However, he could not understand and pronounce other people’s names, which are considered as a social stimulus. Before this study, Ken had performed dictated name => picture of face MTS tasks for a long period, but he could not learn these social pairing relations.

Taro was a 10-years-7-months old boy who was enrolled in a special education class at a public elementary school. On the Kyoto Scale of Psychological Development, he had a measured overall developmental quotient (DQ) of 55 (Cognitive-Adaptive DQ of 63 and Language-Social DQ of 48). Taro could understand and speak easy sentences consisting of two or four words, and he could read all

Hiragana characters. However, in an assessment conducted prior to this study, he could read only a few Kanji characters, which are imparted in the first grade in Japanese elementary schools.

2.2. Stimuli and apparatus

In Ken’s training, six pictures of people’s faces and six corresponding printed names written in Hiragana and Kanji characters were used as training stimuli (see Table 1). All the people in these pictures were Ken’s therapists, but Ken could name none of them. He could, however, read the printed names fluently. These pictures and printed names were assigned to two stimulus sets, each of which included three people’s pictures and printed names (see Table 1).

In Taro’s training, 18 Kanji characters that were selected from Kyoiku Kanji (Ministry of Education, Science and Culture, 1998), 15 auditory stimuli, and 15 picture stimuli were used. The auditory and picture stimuli corresponded to the reading and meaning of each Kanji character (see Table 1). These Kanji characters, auditory stimuli, and picture stimuli were assigned to five stimulus sets, each of which included three equivalence relations (i.e., Kanji character–auditory stimulus–picture stimulus), and one pretraining stimulus set that included only three Kanji characters (see Table 1).

MTS tasks and stimulus pairing tasks in this study were mostly conducted using a personal computer. A touch-sensitive screen was used for Ken to show the stimuli and to detect his responses. Taro used a laptop computer’s monitor and mouse to display the stimuli and to indicate his responses, respectively. All these computer tasks were controlled by a program developed using Visual Basic.NET, and the boys’ responses were recorded by a computer.

## 2.3. Procedures

### 2.3.1. Pretraining

In pretraining, Taro performed three choices of identity MTS training and testing to ensure his capability to perform MTS tasks on a computer. Ken did not perform these pretraining tasks because he already had some experience in identity MTS training and testing on a computer before this study. In the identity MTS training trial, a Kanji character was presented as a sample stimulus in the upper center of the screen. Three Kanji characters were presented horizontally as comparison stimuli in the lower half of the screen immediately after Taro clicked the sample stimulus with the mouse. When Taro selected a comparison stimulus identical to the sample stimulus, all stimuli on the monitor were deleted, and reinforcing stimuli (a picture of a red circle and a short fanfare) were presented for 1.2 seconds. When he did not select a correct comparison stimulus, an identical trial with the same stimulus arrangement was repeated until he could select the correct stimulus (i.e., retrials were conducted). Correct choices in retrials were also reinforced but were recorded as incorrect choices. All nine trials were conducted in one training block. Each Kanji character was presented as a sample stimulus three times in a random sequence during one block. The positions of correct comparison stimuli were changed so that they were not the same for more than three successive trials. Intertrial intervals (ITI) were of 1 second each, during which a blank screen was displayed. After termination of the final trial of every block, Taro’s favorite picture (e.g., animal picture) was presented on the monitor for 7 seconds, regardless of his performance in the MTS task. If Taro showed correct choices in all training trials of one block, he performed an identity MTS test in the next block. The identity MTS test was identical to the identity MTS training but without any reinforcing stimuli and any retrials after wrong choices. When Taro showed correct choices in all the test trials of one block, the baseline phase was initiated.

2.3.2. Baseline phase

In the baseline phase, MTS tests were conducted to assess the learning of target stimulus relations prior to the stimulus pairing tasks. All nine trials were conducted in one test block.

Ken performed picture of face => printed name MTS tests. These MTS tests for Ken were almost identical to the identity MTS test in the pretraining, except that pictures of faces were used as sample stimuli and printed names as comparison stimuli. Neither reinforcing stimuli nor retrials were presented in these MTS tests. However, the favorite picture stimuli after the final trials of the block that were presented in Taro’s identity MTS tests were not presented for Ken. Instead, we interspersed the picture of face

=> printed name MTS test block among the nine picture of face => picture of face identity MTS training trials to maintain Ken’s motivation. In these identity MTS training trials, Ken’s favorite pictures (e.g., characters of TV games) were presented with a short fanfare for his correct choices.

Taro performed three types of MTS tests in one test block: three trials of auditory stimuli => picture stimuli, three trials of picture stimuli => Kanji characters, and three trials of auditory stimuli => Kanji characters. The procedure of Taro’s MTS test was almost identical to Ken’s MTS test in the baseline phase. In Taro’s MTS tests, however, identity MTS training trials were not added to maintain his motivation, but his favorite picture stimuli after the final trials of the block were presented as in his identity MTS test in pretraining.

2.3.3. Stimulus pairing training phase

In the stimulus pairing training phase, the participants observed multiple stimulus pairs of each stimulus set just before MTS tests, which were identical to those in the baseline phase. In each of these stimulus pairs, two corresponding stimuli (i.e., correct stimulus relations shown in Table 1) were paired in succession.

Ken observed pictures of face and printed name pairs in the stimulus pairing training. In one of Ken’s stimulus pairing trials, one picture of face was presented at a random position on the touch sensitive monitor at the start. After he touched the face, the picture was cleared, and the corresponding printed name was presented in the same position immediately for 2 seconds. Following a 1-second blank screen, the next picture of face was presented in the same manner. For simplicity, we describe such stimulus pairing as “picture of face >> printed name,” hereafter. The left side of the arrow (>>) represents the paired stimulus presented first, and the right side represents the paired stimulus that followed. Ken observed 24 stimulus pairs during one training block. In each training block, each of the three pictures of face in a stimulus set were paired with corresponding printed names in a random sequence eight times. Immediately after a stimulus pairing training block, one MTS test block was conducted as described above. This cycle of stimulus pairing training and MTS test was repeated until his correct choice responses in the MTS test were stabilized. Prior to stimulus pairing training, we instructed Ken to carefully observe the stimuli presented on the monitor, but we did not refer to the relationship between stimulus pairing training and the MTS test. After the third block of stimulus pairing training, we prompted Ken to read the printed name aloud to concentrate his attention to the printed name. We did not present an auditory model of the reading to ensure the stimulus pairing between visual stimuli even if he did not read aloud in some trials.

Taro observed Kanji character >> auditory stimulus pairing in each training block. In Taro’s stimulus pairing trial, one Kanji character was presented at random positions on the monitor at the start. After he clicked the Kanji character, the Kanji was cleared and the corresponding auditory stimulus was presented immediately. Following a 1-second blank screen, the next Kanji character was presented in the same manner. Taro observed 12 stimulus pairs during one training block. In each training block, each of the three Kanji characters in a stimulus set were paired with a corresponding auditory stimulus in a random sequence four times. Immediately after the stimulus pairing training block, one MTS test block was conducted. Unlike the baseline phase, Taro conducted six trials per block of MTS tests, which included two types of MTS tests from his baseline phase. That is, three trials of a MTS test of symmetrical relations of stimulus pairing (i.e., auditory stimulus => Kanji character MTS test) and three trials of an auditory stimulus => Kanji character MTS test were presented in each MTS test block. This cycle of stimulus pairing training and MTS test was repeated until his correct choice responses were stabilized. When Taro correctly chose comparison stimuli perfectly for three successive MTS test blocks (two successive MTS test blocks after the fourth stimulus set), the probe phase was initiated. If Taro could not choose correct comparison stimuli perfectly for four successive MTS test blocks, the cycle of stimulus pairing and MTS test was interrupted.

2.3.4. Probe phase

The probe phase was implemented only for Taro. In this phase, MTS and reading tests were conducted without stimulus pairing training. In the MTS tests block, three types of MTS tests identical to those of the baseline phase were assessed: that is, MTS tests of symmetrical relations, i.e., auditory stimulus => Kanji character MTS tests, equivalence relations, i.e., Kanji character => picture MTS tests, and auditory stimulus => picture MTS tests were conducted. In addition, another test block that consisted of three trials of auditory stimulus => picture MTS tests, three trials of Kanji character => picture MTS tests, and three trials of Kanji character => auditory stimulus reading tests was also conducted. In the reading test trial, Taro was prompted to read aloud one Kanji character presented in the upper center of the screen. Neither corrective feedbacks nor verbal models of correct responses were presented for his reading responses. To assess the maintenance of learning, we repeated this probe phase in some stimulus sets for one to four weeks after the stimulus pairing training was terminated.

### 2.3.5. Generalization probe

The generalization probe was implemented only for Ken. In this probe, Ken was prompted to answer the names of five people who were in front of him, referring to an A4 size sheet on which six people’s names were printed. One person was absent from the generalization probe. Neither corrective feedback nor verbal models of correct names were presented for Ken’s responses.

## 2.4. Experimental design

To assess the effects of stimulus pairing training, we used a multiple probe design between stimulus sets for Ken’s training and a nonconcurrent multiple baseline design between Stimulus Sets (Watson & Workman, 1981) for Taro’s training.

3. Results

Fig. 1 shows the percentage of correct choices in Ken’s MTS tests during the baseline phase and the stimulus pairing training phase. Fig. 2 shows the percentage of correct choices in Taro’s MTS tests during the baseline phase, the stimulus pairing training phase, and the probe phase. However, we drop all auditory stimulus => picture MTS test data from the figure because it was at 100% across all the phases. We describe each result separately in the following sections.

In baseline phase of Stimulus Sets 1 and 2, Ken showed a high percentage of correct choices in the identity MTS training, while he showed a low percentage of correct choices (i.e., chance-level performance) in the MTS tests. After the stimulus pairing training was introduced in Stimulus Set 1, he showed no increasing trend in the MTS test performance. Thus, we prompted Ken to read aloud the printed names, which were paired with pictures of faces, after the third block of the stimulus pairing training phase (the white arrow in Fig. 1 indicates the start point of this adjustment). This reading behavior (i.e., observing behavior) seemed to increase his performance in the MTS test, however, this performance level was not maintained. During the MTS tests, Ken seemed to select a certain position of stimulus as soon as the comparison stimuli were presented. We assumed that Ken showed these behavioral patterns to perform MTS tasks with reinforcement stimuli (i.e., identity MTS trails) as soon as possible. Therefore, we removed all identity MTS trials from his MTS test after the eighth block of the stimulus pairing training phase. Furthermore, to maintain Ken’s motivation, his favorite item (e.g., a small cup of his favorite drink) was delivered after the final trial of each MTS test regardless of his performance in the MTS test block. After the removal of identity MTS trials, he reached his first 100% correct choice score in the thirteenth block of the stimulus pairing training phase. While some instability was observed, he exhibited 100% performance in six out of eight MTS test blocks after that. During the baseline phase of Stimulus Set 2, Ken could not select the corresponding printed name with each picture of face as in Stimulus Set 1. He also could not select the correct stimulus after identity MTS trials were removed and reinforcing stimulus began to be delivered after the final trial of the MTS test, regardless of his performance in the test block. However, when stimulus pairing training was introduced for Stimulus Set 2, he could select the correct printed name in the next MTS test block perfectly. He exhibited 100% performance in four out of five MTS test blocks after that. The generalization probe was implemented after he exhibited 100% performance in both stimulus sets. However, in the generalization probe, Ken could correctly match only one person’s name.

In the baseline phase of all stimulus sets, Taro exhibited a high percentage of correct choice in auditory stimulus => picture MTS test trials, while he exhibited a chance-level performance in auditory stimulus => Kanji character and picture => Kanji character MTS test trials. After the stimulus pairing training (i.e., Kanji character >> auditory stimulus) was introduced, symmetrical relations (i.e., correct auditory stimulus => Kanji character MTS performances) were derived in the MTS tests of Stimulus Sets 1, 3-5. In the probe phase of these stimulus sets, he showed both derived symmetrical and equivalent relations (i.e., correct picture => Kanji character MTS performances). In Stimulus Set 2, Taro could not show the derived symmetrical relations in the MTS test block after the stimulus pairing training, and then the stimulus pairing training phase was disrupted. However, when we reintroduced stimulus pairing training for Stimulus Set 2 after he learned the multiple stimulus sets (i.e., Stimulus Sets 3-5) with the training, he could derive symmetrical relations. In probe phase, the maintenance of symmetrical relations and the derivation of equivalent relations were observed in Stimulus Set 2. The reading tests were implemented in Stimulus Sets 2-5 after the symmetrical and equivalent relations were observed in the MTS test. Taro could read all the Kanji characters in these stimulus sets. He also showed good maintenance of learning in an assessment one week later, but he showed unstable maintenance in the assessments two or more weeks later.

4. Discussions

In this study, we examined the effectiveness of stimulus pairing training for two boys with ASDs. During the stimulus pairing training, one participant observed stimulus pairings between visual stimuli (i.e., pictures of faces >> printed names pairing) as in most previous studies, while the other participant observed stimulus pairing between a visual stimulus and an auditory stimulus (i.e., Kanji characters >> auditory stimuli pairing). We found that both the participants demonstrated their learning of each target stimulus relation with stimulus pairing training, validating that stimulus pairing can promote not only the learning of the relations between identical stimulus modality but also those between different stimulus modalities. The result indicated that the stimulus pairing training procedure could be effective to promote the learning of language and cognitive skills in children with ASDs. This result is very important because children with ASDs often show a tendency to persist in their irrelevant stimulus control in MTS tasks, as we mentioned earlier.

This study also suggested some factors that may promote the learning of stimulus pairing training. The first is the learning history of stimulus pairing training with more than one stimulus sets. For example, in Ken’s Stimulus Set 1, it took 13 cycles of stimulus pairing and MTS tests for him to accomplish his first perfect MTS test performance. However, in his Stimulus Set 2, he accomplished his first perfect MTS test performance only after one cycle. In the case of Taro, he could not learn in the first stimulus pairing training with Stimulus Set 2, but he could learn Stimulus Set 2 rapidly after he had learned other multiple stimulus sets (i.e., Stimulus Sets 3-5) with stimulus pairing training. These data may indicate the evidence of “learning sets” (Mazur, 1998) in stimulus pairing training. The second is the preference of stimulus. For example, Taro could not learn Stimulus Set 2 with stimulus pairing training, although he could learn other stimulus sets easily. As one reason for these different learning outcomes, we infer differences in preference. That is, the stimuli used in Stimulus Sets 1, 3, 4, and 5 included Taro’s preferred stimuli (e.g., animals or insects), but the stimuli used in Stimulus Set 2 did not include his preferred stimuli (e.g., color patches). However, there is a scope for further investigation into whether such preferences actually affect the learning of stimulus pairing.

This study also revealed some issues that have to be considered in applying stimulus pairing training to language and cognitive skills training in children with ASDs. The first is the generalization of learning through stimulus pairing training. In Ken’s stimulus pairing training, the learning did not generalize. However, it is not clear in this study whether this lack of generalization is a property of stimulus pairing learning. Another possible explanation for the lack of generalization may be that the difference in task structure between MTS tests and generalization tests might affect the lack of generalization in this study. For example, in a MTS test trial, only one picture of a person’s face was presented as sample stimulus, and only three printed names were presented as comparison stimuli. However, in a generalization test trial, all five people were seated in front of Ken, and all six names were printed on an A4 size sheet. In addition, there is also a great difference between the target behaviors in each test. That is, Ken had to touch one of the printed names to select in the MTS test trial, while he had to pronounce a person’s name in the generalization test trial. Some previous studies showed that a small difference in the task structure distorted the generalization of learning in children with ASDs (Kelly, Green, & Sidman, 1997). To determine whether this lack of generalization results from stimulus pairing training, further systematic empirical research would be needed. The second is the maintenance of learning after stimulus pairing training. Taro showed good maintenance in an assessment one week later, but he showed unstable performance in assessments two or more weeks later. However, it is not clear in this study whether this unstable maintenance of learning is a property of stimulus pairing learning. Further research would be necessary to resolve this issue as well as the generalization problems. The third is the examination of the effectiveness of some modifications in the stimulus pairing training procedure. It is said that children with ASDs often have difficulties in attending to relevant stimulus features. Thus, in this study we modified some stimulus pairing training procedures to concentrate the participant’s attention to relevant stimuli.

For example, the participants were required to touch or click the stimuli presented at random positions on their monitors. In addition, Ken was required to read aloud the printed names presented after the pictures of faces. It is not clear whether these modifications actually promoted the stimulus pairing learning in children with ASDs. In MTS tasks, it was demonstrated that such observing responses improve task performance in individuals with mental retardation (Dube & McIlvane, 1999). Thus, further research is needed to clarify whether these observing responses and presentation methods actually work to improve the learning of stimulus pairing. Finally, we did not directly compare the effectiveness or efficiency of the stimulus pairing with MTS training in this study. Previous studies that directly compared stimulus pairing with MTS training in adults with typical development yielded inconsistent results (Leader & Barnes-Holmes, 2001; Clayton & Hayes, 2004). To clarify the effectiveness or efficiency of the stimulus pairing in children with ASDs, direct comparison studies are necessary. Studies that examine the conditions in which children with ASDs can learn effectively or efficiently through the stimulus pairing training are also needed.

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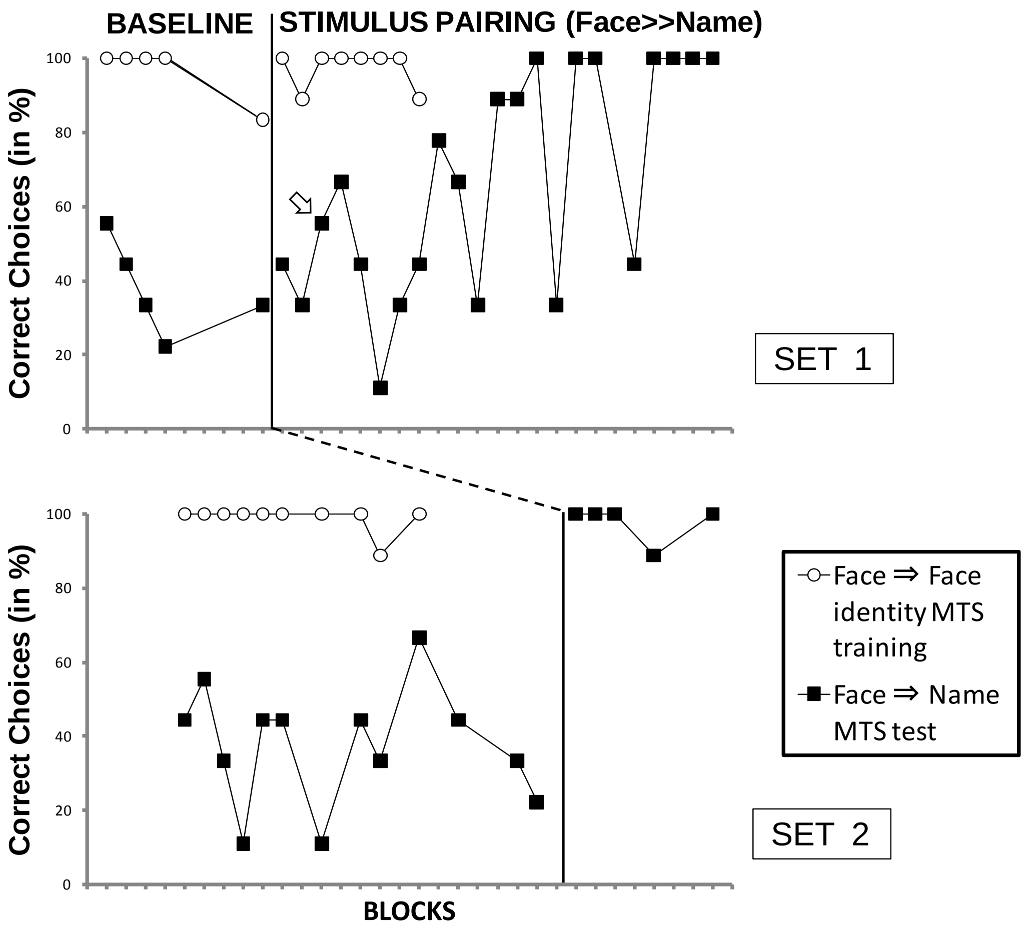


Fig. 1 Percentage of Correct Choices in Ken’s MTS Test Block

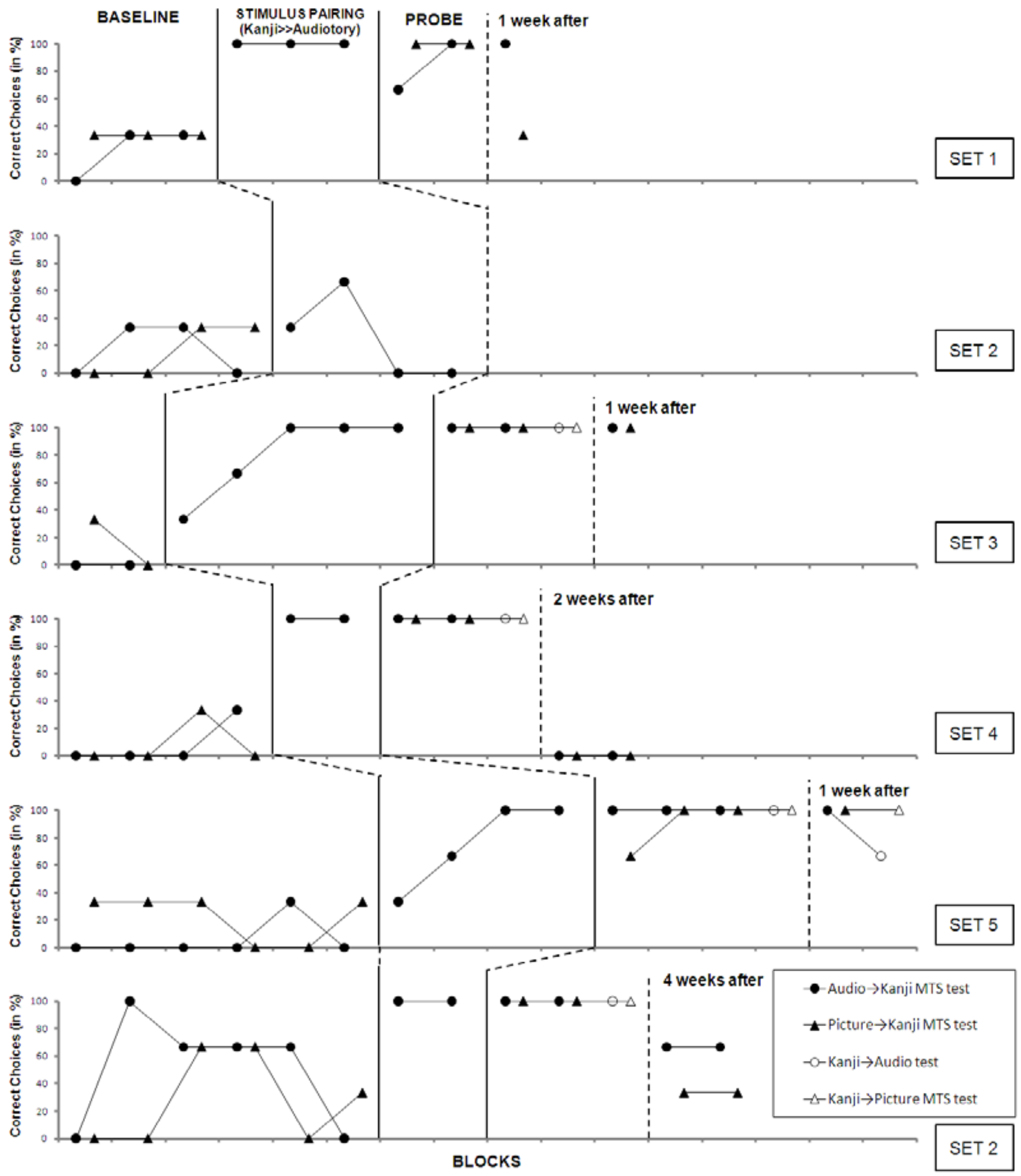


Fig. 2 Percentage of Correct Choices in Taro’s MTS Test Block

Table 1 Stimulus Sets Used in This Study